SESSION VII: VEGETATIVE COVERS

Monitoring Alternative Covers

Craig Benson, University of Wisconsin

Craig Benson said that many people have expressed interest in using vegetated covers as an alternative to prescriptive RCRA-style landfill covers. He said that this is because the latter, which do not always perform well, typically cost a great deal of money. For example, compacted clay caps, which are listed under RCRA Subtitle D, cost about $125,000 per acre and are prone to desiccation cracking, frost damage, settlement, and root intrusion. Other prescribed covers, such as composite-type caps, do perform well, but these cost between $175,000 to $200,000 per acre. Benson said that investigators are confident that effective vegetative covers can be designed for far less money. He said that vegetative covers, like any landfill cover, must (1) prevent physical contact with underlying waste, (2) prevent harmful gas production, and (3) keep water from percolating downward toward groundwater tables. The latter objective, he said, is of paramount importance; he described how vegetative covers achieve it. The covers act like sponges: they have thick soil layers that hold water during dormant seasons, and are sucked dry during the growing season, when plant roots extract stored water. If a vegetative cover is designed so that soil storage capacity is never exceeded, Benson said, water will not leak into underlying wastes. There are two basic types of vegetative covers: monolithic barriers and capillary barriers. While a cap of the former type simply consists of a thick layer of dirt with vegetation on top of it, Benson said, a cap of the latter type has fine textured soils laid over coarser materials. The contrast in texture in the latter design buoys water up in the top layers, making the water more accessible to plant roots.

Benson said that several test covers have been installed under the Alternative Cover Assessment Program (ACAP). One of the main goals of ACAP is to determine whether vegetative covers perform as well as prescriptive designs. This must be determined, Benson said, because RCRA Subtitle D states that percolation from an alternative cover must be less than or equal to percolation from prescriptive covers. At many sites, Benson said, ACAP has installed vegetative and prescriptive covers side by side, believing that this is truly the best way to compare the percolation rates of the two. At some sites, it was not possible to set up side-by-side comparisons, and ACAP was forced to use default equivalency values to determine whether vegetative caps are equivalent to prescribed covers. For composite caps, he said, these values have been defined as 30 millimeters of percolation per year in humid environments and 10 millimeters per year in arid areas. With composite covers, he said, percolation default values are 3 millimeters per year in both humid and arid environments. (Regulatory documents do not list the amount of percolation that is allowed for prescriptive covers. Thus, ACAP had to define these default values.)

Benson said that ACAP is using an elaborate monitoring system at the demonstration sites. Test sections have been set up with lysimeters so that any drainage that leaks through a cover can be measured directly. The lysimeters are like big pans; each sits on a compacted base that is about 10 meters by 20 meters in size. The bottom layer of each lysimeter consists of an impervious geomembrane that is made of a low-density polyethylene. A geocomposite drainage layer lies over the geomembrane and carries any infiltrating water to a collection sump, which in turn shuttles the water to tipping buckets and siphons so that drainage can be measured. An interim soil cover is placed over the drainage layer, Benson said, and a root barrier is placed on top of that. (The barrier has an herbicide; roots that come in contact are redirected, but not killed.) The test cover sits on top of the root barrier. Benson said that careful quality control is performed when lysimeters are installed; for example, geomembrane seams are examined and test systems are filled with water to determine whether leaks are present. Aside from the lysimeters, Benson said, a variety of other monitoring systems are established at ACAP sites. For example, weather stations are set up to collect meteorological data, and a variety of water content reflectometers, thermocouples, and heat dissipation probes are installed. All of the monitoring systems, he said, are wired to solar-powered data loggers, which transmit data to the Desert Research Institute in a near-real-time fashion. These data are collected, organized, and made available to ACAP members *via* the Internet. Users can select specific parameters that interest them, Benson said, and graph the parameters over specified time periods. He said that access to the data is currently limited to those who have passwords, but the data will eventually be made public in published reports.

Growing a Thousand-Year Landfill Cover
William Jody Waugh, MacTec-ERS

Jody Waugh said that the U.S. Department of Energy (DOE) wants to design covers that perform adequately for 1,000 years or more. These kinds of covers are needed to isolate radioactive wastes (*e.g.*, uranium mill tailings and fission products). About 20 years ago, Waugh said, DOE started capping sites under the Uranium Mill Tailings Radiation Control Act (UMTRCA) project. As part of this effort, many sites were covered with compacted soil layers, a fine sand layer, and rock rip-rap. (Caps like this were installed in Tuba City, Arizona; Rifle, Colorado; Mexican Hat, Utah; and Lowman, Idaho.) Some vegetative caps were also installed, Waugh said. Vegetative caps of various kinds were installed at sites in Pennsylvania, Utah, and Colorado. Waugh said that DOE is assessing the lessons that have been learned on the UMTRCA covers, and will take these into account when designing the next generation of DOE covers, which are to be installed at DOE weapon sites. Waugh said that DOE will compile what it has learned in a guidance document on how to design covers for long-term performance. This document will help end users, he said, and will hopefully be embraced by the regulatory community.

Waugh said that all covers are subjected to dynamic ecosystems, and that a site's ecology changes over the long term. Thus, it is not realistic to use data from a short field study to predict cover performance in future centuries. More accurate predictions can be made, he said, if monitoring efforts, modeling efforts, and analog studies are combined to make these estimates. The latter involves evaluating natural or archaeological settings. By looking at analogs, Waugh said, researchers reconstruct the past and collect clues that can be used to predict what will happen in the future. He said that researchers can use analogs to gain an understanding of how pedogenesis (*i.e.,* soil development), ecological change, and climatic change could impact covers. With this information in hand, DOE might be able to design covers that endure changing conditions over the centuries. If so, this may save DOE billions of dollars in stewardship costs.

Waugh said that pedogenesis could affect the physical and hydraulic properties of a cover over time. He said that designers can obtain an idea of how their engineered caps might develop if they evaluate natural or archeological settings that have soil profiles similar to the engineered soils. For example, he said, researchers were able to predict how soil would develop in a cover that was installed in Monticello, Utah, by analyzing how soils developed in Anasazi pit houses that were abandoned about 800 to 1,000 years ago. Also, he said, by evaluating a natural capillary barrier that formed in the state of Washington, researchers learned about the water-holding capacity of a certain soil that was used at the Hanford DOE site. This natural barrier, which has a soil profile that is about 13,000 years old, has fine materials deposited over a coarse layer. Waugh said that carbonates, which serve as tracers for water movement, were found on the coarse materials. This means that the thin layer of fine soil was not thick enough to prevent downward percolation. Thus, if this material were used in a vegetative cover design, the layer would have to be made thicker.

Waugh said that ecological changes, such as plant succession and biological intrusion, can have dramatic impacts on a cover's evapotranspiration rate. He said that analogs were used to predict the impact of preferential flow on a cover that was installed in Pennsylvania. This cover has a clay layer that is overlain by a layer of sand and a layer of rock. Plants have penetrated the top two layers and have started establishing in the clay layer. *In situ* saturated hydraulic conductivity was measured in areas that had plants, as well as areas that had not been invaded. Values were about 10^{-7} cm/sec in the plant-free areas, but were two orders of magnitude higher near Japanese knotweed plants. Waugh said that the values detected near the plants were close to what was measured at an analog site that also had plants established. He also said studying natural environments has helped researchers at the Hanford site determine what potential vegetation patterns could emerge if area soils were incorporated into cover design. In addition, studies have been performed at an UMTRCA site near Lakeview, Oregon, to determine how leaf area index values change when plants invade an area.

Waugh said that climatic changes also occur over the long term, and that changes in meteorological parameters could have dramatic impacts on cover performance. Thus, when designing a cover to perform over the long term, researchers should evaluate natural paleoclimate analogs to obtain reasonable estimates of how climate could change in a certain area in the future. That way, the range of climate changes in the past can be entered as bounds in design models. Waugh described how climatic conditions in the Four Corners area were reconstructed. He said that pollen cores, packrat middens, and other proxy climate data were used to reconstruct past plant populations, and this helped to determine what past climates were like.

Tree Covers for Containment and Leachate Recirculation
Eric Aitchison, Ecolotree, Inc.

Eric Aitchison described the Ecolotree® Cap, a patented containment system designed to achieve hydraulic control. This cap, which consists of densely planted hybrid poplars and a grass understory, acts like a sponge, holding moisture during dormant seasons and then drying out during the growing season. Aitchison said that poplars are used in the Ecolotree® Cap because these trees grow fast, tolerate a variety of environmental and chemical stressors, develop deep and dense root systems, are relatively easy to plant and maintain, can be grown from cut stumps, and can be used as a cash crop. Aitchison said that Ecolotree® Caps have been installed at several sites across the county. He described six of them:

Ecolotree® Cap Projects
Lakeside Reclamation Landfill in Beaverton, Oregon: The first Ecolotree® Cap, designed to cover a 3-acre area with 11,000 hybrid poplars, was installed at this site in 1990. About 90% of the trees survived, and trees grow about 5 to 8 feet each year. Tree roots have grown through a 4-foot-thick soil layer and have penetrated the site's wastes. No contaminants have been detected in monitoring wells since the cap was installed. The site owner is happy with the system, and recently received approval to extend the cap over the entire site. The Ecolotree® Cap has also improved aesthetics and has attracted wildlife. The site owner has brought sheep in to graze among the trees.
The Bluestem Landfill in Cedar Rapids, Iowa: At this site, an Ecolotree® Cap was compared to a prescriptive cover that the Iowa Department of Natural Resources approved. Soil moisture was measured with reflectometers between November 1995 and October 1996. At all times, soil moisture was lower in the Ecolotree® Cap than in the prescribed cover. (Soils did not exceed the water-holding capacity in either cap.) In addition to achieving environmental objectives, the Ecolotree® Cap served a secondary purpose: the trees trapped and prevented litter from blowing off site.
PAH-contaminated site in Tennessee: Before planting, compost was spread over this site to improve soil fertility and water-holding capacity. The Ecolotree® Cap is expected to serve three purposes at this site: (1) achieve hydraulic control, (2) stabilize soil, and (3) enhance rhizosphere degradation.
Landfill in Seattle, Washington: The Ecolotree® Cap will not be able to achieve complete hydraulic control at this site because it receives too much winter rain. Modeling has been performed; the results suggest that the cap could reduce leachate production by 50%. For this site, regulators decided that this partial reduction is sufficient. So, the cap was installed over 13 acres in April 2000. The project cost about $600,000. Site owners believe that a geomembrane would have cost about $3,000,000 to install at this site.
Military base in Georgia: A side-by-side comparison is being performed between the Ecolotree® Cap and a prescribed cover. This work is being performed under ACAP.
Landfill in Michigan: Site owners told Ecolotree, Inc., representatives that the site's soils were suitable for plant growth. Thus, an Ecolotree® Cap was installed over a chemical waste landfill. When only 30% of the trees survived, a more detailed soil and groundwater sampling effort was conducted. Results showed that the site has high salinity and pH values. Greenhouse studies were performed to determine whether amendments could make the soils fertile. Results are promising, but site owners have not yet decided how to move forward

Aitchison also described the Ecolotree® Buffer, which was patented in summer 2000. In this system, he said, plants are exposed to contaminated water in a flow-through fashion. For example, waste water or leachate is used as irrigation for Ecolotree® Buffers. Aitchison described three sites where Ecolotree® Buffers have been used:

Ecolotree® Buffer Projects
Riverbend Landfill, McMinnville, Oregon: About 35,000 hybrid poplar trees were planted over 17 acres in 1992 and 1993. Ammonium-rich leachate is shuttled from a collection pond to the tree plantation and used as irrigation water. In the fourth growing season, about 860,000 gallons of leachate were applied to each acre of the plantation, and about 460 pounds of nitrogen was added per acre. By the end of the growing season, only about 30 pounds of nitrogen were found in the soils. (Investigators know that the nitrogen is not simply being flushed out of the system because Time Domain Reflectometry probes have been installed to determine whether water is moving downward.) Roots were shown to extend about 7 feet bgs, and leaf matter was also detected at this depth. It is believed that worms are dragging the organic material down, and that this will improve soil fertility and water-holding capacity. Ecolotree, Inc., and CH_2M Hill received an award for this project.
City of Woodburn Wastewater Treatment Plant: About 17,000 hybrid poplars were planted over 10 acres in 1995. In 1999, the project was extended over a 90-acre area. The goal was to remove thermal energy and ammonium from treated wastewater. Wastewater was used to irrigate the site during the summer months. Ecolotree, Inc., and CH_2M Hill received an award for this project.
GRRWA Landfill, Fort Madison, Iowa: About 6,800 hybrid poplar trees were planted over 6 acres in 1997 and 1998. Site managers installed the system in an effort to treat leachate in a cost-effective manner. Before installing the Ecolotree® Buffer, the managers paid about $150,000 annually to dispose of 7,000,000 gallons of leachate. After installing the plantation, site owners only had to dispose of 50,000 gallons. The trees transpired or absorbed the remainder. Leachate was sprayed right onto tree leaves. This burned the leaves, so site managers started irrigating at night so that materials would not get baked onto the leaves. Stanley Consultants and Ecolotree, Inc., received an award for this project.

EPA Draft Guidance on Landfill Covers

Andrea McLaughlin and Ken Skahn, EPA, Office of Emergency and Remedial Response

Andrea McLaughlin described regulatory frameworks, and explained what site managers must do to obtain approval to use alternative covers. Under the EPA Liquids Management Strategy, she said, landfill owners are expected to detect, collect, and remove any leachate that is generated in their landfills. In addition, owners are expected to prevent leachate generation by preventing liquids from percolating through waste materials.

McLaughlin described what is expected of landfills that are closed under RCRA Subtitle D. First, she said, permeability of bottom layers must be greater than or equal to those of top layers. Also, permeability rates may not be greater than 1×10^{-5} cm/sec. McLaughlin said that federal regulations explicitly indicate that state officials can approve alternative covers as long as the cap is able to achieve equivalent reductions in infiltration (*i.e.,* permeability must not exceed a rate of 1×10^{-5} cm/sec). McLaughlin said that some states may have even stricter performance standards. For example, in Illinois, covers must be designed so that they do not exceed infiltration rates of 1×10^{-7}cm/sec. McLaughlin said that covers that are selected for CERCLA-mandated landfills are expected to meet ARARs—standards or requirements that are specified under federal laws or promulgated under state environmental laws. According to federal regulations, she said, alternative covers may be used at CERCLA sites in states that already have provisions for alternative covers written into state law. If no such provision exists, alternative covers can still be considered as a potential remedial approach if ARAR waivers are obtained. These waivers can be obtained, she said, if an alternative cover is shown to perform at least as well as prescribed covers. To prove this, site owners must show that the alternative cover infiltration rate does not exceed the minimum permeability rate that is defined under RCRA Subtitle D. McLaughlin stressed that alternative covers must be able to meet the minimum permeability standards at all times, rather than over an averaged period. If an ARAR waiver is obtained, and an alternative cover meets the nine criteria of the National Contingency Plan, then the cover will be considered a viable remedial approach.

McLaughlin said that two EPA guidance documents are being developed under the EPA Liquid Management Strategy. One will address the use of alternative covers at CERCLA municipal landfills, and the other will provide comprehensive technical guidance on RCRA/CERCLA final covers. Ken Skahn is leading the effort to develop the latter, McLaughlin said. She turned the remainder of the presentation over to him.

Skahn said that EPA's technical guidance on RCRA/CERCLA final covers will be released in about 18 months. It will serve as an update to a previous guidance document that was written in 1991. He said that an update is needed because existing RCRA guidance documents do not discuss landfill gas managment, performance monitoring, or long-term maintenance. In addition, existing documents do not discuss alternative covers or list cover materials (*e.g.,* geocomposite clay liners and new drainage materials) that have become available over the last decade. Skahn said that it is important to discuss new materials because some state regulatory agencies are reluctant to use new materials until the materials are officially acknowledged by EPA. Skahn said that the revised guidance document will cover the following topics: regulatory requirements, design considerations, alternative designs, water balance models, geotechnical analysis and design, lessons learned, and long-term maintenance. He said that the document will explain that alternative covers can be used if the covers demonstrate equivalency, and that this can be proven either with predictive models or side-by-side demonstrations. Skahn said that the document will explain that covers can be designed to last for long periods if designers select appropriate materials and address slope stability, erosion, long-term maintenance, and flow capacities for internal drainage systems. In addition, the document will encourage designers to take the following steps: (1) determine if gas collection is necessary, (2) identify critical infiltration events, (3) calculate minimum storage capacity, (4) characterize soil properties, (5) identify appropriate cover thickness, (6) consider amending surface soils and installing vegetation, and (7) use predictive modeling to establish the adequacy of proposed designs.

Activities at an EPA Region 3 Site
Donna McCartney, EPA, Region 3

Donna McCartney described a site that received wastes from a chlorine manufacturer, a PCB manufacturer, and a neighboring facility for more than a decade. These wastes were disposed in two disposal impoundments. In February 2000, she said, approval was granted to test a vegetative cover as a potential containment measure for this site. Site managers are hopeful that the cover will reduce infiltration, mitigate erosion, eliminate direct contact with wastes, and promote contaminant degradation. The cover will be analyzed over a three-year period; if proven effective, the cover may be considered as a viable remedial approach during final remedy selection.

Speaker Panel and Audience Discussion

Audience members asked questions or provided comments about the following topics:

- *Measuring performance.* One attendee called attention to one of the comments that McLaughlin made during her presentation: alternative covers are expected to meet RCRA Subtitle D permeability standards at all times. He thought this was excessively strict, and asked whether the regulations would permit momentary lapses following extreme weather events, such as a 500-year rain. McLaughlin said that the regulations imply that no exceedences are acceptable. She recommended designing covers so that they are able to perform effectively during extreme events.

- *Percolation rates* versus *amounts*. Rock said that the regulations list percolation rates that cannot be exceeded, but that these rates are not translated into actual amounts. He said that it is difficult to measure rates in the field. Thus, many investigators are measuring drainage amounts instead, and performing side-by-side comparisons to determine whether vegetative caps are equivalent to prescribed covers.

- *Guidance documents for alternative covers*. Erickson asked whether guidance documents have been produced on vegetative cover designs. Waugh said that DOE created a guidance document that describes how to design UMTRCA covers. In addition, he said, DOE plans to release another guidance document in about three or four years. Rock said that ACAP has not developed guidance documents yet. Both he and Benson stressed that vegetative cover designs are very site-specific; one design cannot be applied to all sites. Aitchison agreed that vegetative cover designs are site-specific, but said that it might be possible to make some general design recommendations at this point. For example, he said, it might be realistic to say that the top layers of a vegetative cover should never be less than 18 inches thick. If thinner layers are used, he said, plants might be killed by high methane levels.